From: Cheryl Brown

Date 10/12/2016

Subject: Review of Pteropod and aragonite saturation data from 2011 and 2013

This document explains how Figure 3 in Bednarsek et al. (2014) was recreated using the 2011 data provided by NOAA in email from Rochelle Labiosa on 7/6/2016 in file "West-Coast-OA-Data_2007_2011_2012_2013_for_WSDE (002).xlsx". The 2013 pteropod data provided included one datapoint that was within Oregon State waters (Station 104). Station 104 is located at latitude 44.65 deg North, and longitude 124.13 deg West and is estimated to be about 3 miles from shore.

The percentage of the water column in the upper 100 m that was undersaturated with respect to aragonite ($\Omega_{arg} < 1$) was calculated, since this variable was not provided in the dataset provided. In the Bednarsek et al (2014) paper it states the following with regard to the calculation of the percent of the water column which is undersaturated:

In Statistical analysis section:

> "We evaluated whether the fraction of undersaturated waters in the top 100 m of the water column (as inferred from our modelled based estimation of Ω_{arg}) was associated with the incidence of severe shell damage (Type II or Type III damage) in this natural habitat of pteropods. At onshore stations where bottom depths were shallower than 100 m, we estimated the fraction of the total water column that was undersaturated."

And in the Results section:

> "To estimate the aragonite saturation state across the full water column, we used the fitted model to predict Ω_{arg} at all depths based on CTD temperature, salinity, and oxygen sensor measurements, from which we calculated the vertically integrated percentage of undersaturation in the first 100 m based on the depth at which the aragonite saturation horizon occurred."

All the carbonate chemistry data had corresponding temperature, salinity and oxygen data and consisted of full profiles. It is unclear how the percent of water column undersaturated was modeled (e.g,. were the models developed using an individual profile or all stations sampled, was spatial interpolation involved, if so what additional temperature, salinity, and oxygen data was used to model Ω_{arg}). For listing purposes, it might be more appropriated to use carbonate chemistry data from where the biological indicator was collected. Therefore, the percent of water column that was undersaturated with respect to aragonite was calculated using each individual station profile that matched the pteropod sample collection station. Profiles were extracted and plotted, and linear regression was used to interpolate between two points that demarked the boundary between saturated and undersaturated (see graphs in Appendix). Figure 1 shows an example of how this was done. If the station was shallower than 100 m, the

maximum station depth was used in calculating the percent of the water column that was undersaturated.

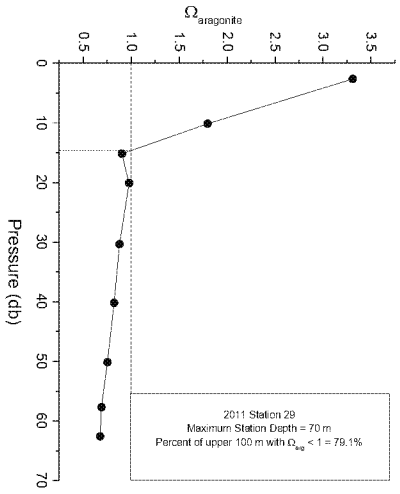


Figure [SEQ Figure * ARABIC]. Station 29 with line showing where Ω_{arg} <1. The percent of water column undersaturated was calculated as 79%.

The coordinates of the pteropod data were compared to the coordinates of the carbonate chemistry data for each station in 2011 and the 2013 datapoint within Oregon State waters (station 104). Three discrepancies were found: the coordinates of pteropod stations 65 and 75 did not match the carbonate chemistry data for these stations in sheet "2011", and similarly for Station 104 from 2013. It was found that carbonate chemistry data from station 64 and 74 matched that for the pteropod sites 65 and 75 from 2011; and in the "2013" sheet station 45 matched that for Station 104 pteropod site from 2013. These sites (64,74, and 45) were used in this analysis.

Percent of water column undersaturated was calculated for the 2011 data and compared to that plotted in Figure 3 of Bednarsek et al. Since the data used to create Figure 3 were not tabulated in the paper, Figure 3 from Bednarsek et al was digitized. For all datapoints except one, the proportion of individuals with dissolution digitized (y-values) agreed exactly with those provided in the Excel spreadsheet (which provides a QA on the digitization); however, one discrepancy was found between the data published in Figure 3 of Bednarsek et al. and the data provided. The proportion of individuals with dissolution at Station 75 was about 0.25 in the published figure; however, in the dataset provided this station has the percent with damage of 0.25. We assumed this was a typo in the dataset provided and the percent was 25% as published in Bednarsek et al. (2014).

There were differences in proportion of water column undersaturated between that using the individual station profile and their modeled values (see Table 1), with some differences as large as 21%. Note: no value was calculated for Station 57 since there was a spike in the profile

Table 1. Comparison of percent of water column undersaturated digitized from Figure 3 in Bednarsek et al. and that calculated using the individual profiles (see Appendix). The last row shows the 2013 data point that is within Oregon State Waters (Station 104).

Station	Station Depth (m)	Percent of Pteropods with Type II & Type 3 damage	Percent of water column undersaturated from Figure 3 (digitized)	Percent of water column undersaturated Calculated from Profile	Difference
6	121	57	82.9	79.2	-3.7
13	90	60	77.6	84.7	7.1
14	45	67	40.0	49.3	9.4
15	46	100	83.3	90.7	7.4
21	2550	25	0.0	0	0.0
28	79	75	82.8	87.2	4.4
29	70	75	65.0	79.1	14.2
31	413	25	40.0	51.3	11.3
37	304	33	31.2	41.7	10.5
57	55	29	15.5		
61	932	33	12.1	12.9	0.7
65 (64 CTD)	60	60	52.7	69.7	17.0
69	518	25	13.0	15.5	2.5
73	4487	0	0.0	0	0.0
75 (74 CTD)	2216	25	30.1	51.3	21.2
87	45	0	0.0	0	0.0
95	41	0	0.0	0	0.0
104 (2013)	43	52	NA	70.2	NA

Figure 2 shows the proportion of pteropods exhibiting dissolution and percent of water column undersaturated for 2011 (calculated using the linear interpolation of profile data) and the one data point within Oregon State waters from 2013 (Station 104, carbonate chemistry from station 45 in sheet "2013"). Figure 3 shows the same data as in Figure 2; however only datapoints offshore of Oregon are included (see Appendix B for a map of stations included). Figure 3 shows that the percent of water column undersaturated ($\Omega < 1$) and percent of pteropods exhibiting shell damage increases close to shore. Figures 4 and 5 shows the strong dependence on station depth for percent of water column undersaturated and percent of pteropods with shell damage for the subset of the data offshore of Oregon. Figure 6 shows the percent of pteropods with shell damage for the full 2011 dataset.

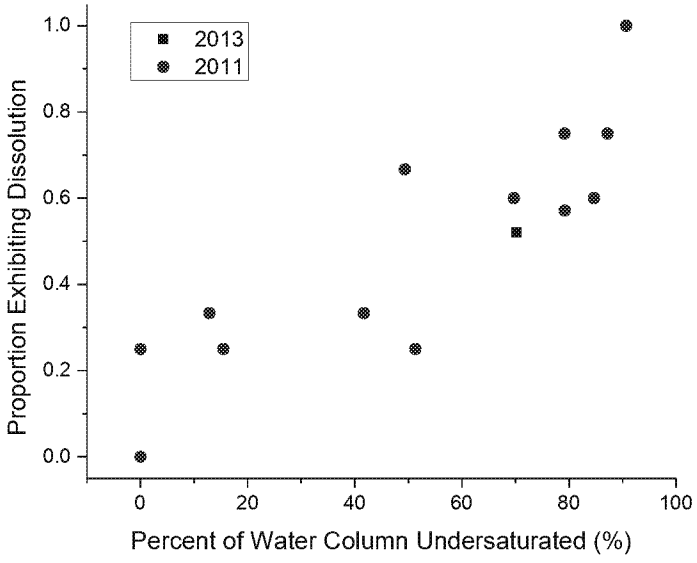


Figure 2. Percent of water column undersaturated and proportion of pteropods exhibiting Type II & III damage with red symbols representing 2011 data and blue symbol representing 2013 data point within OR State waters.

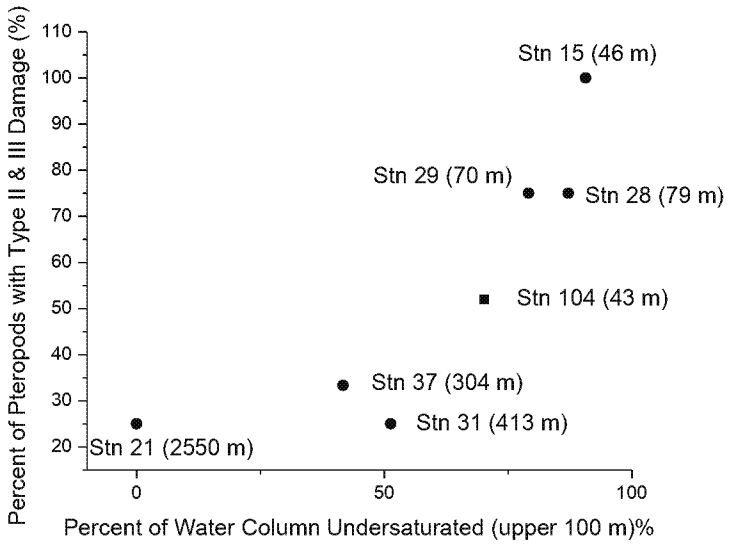


Figure 3. Percent of Pteropods with damage versus Percent of water column undersaturated only using data points off the coast of Oregon. Circles represent 2011 datapoints outside of Oregon state waters, and square is 2013 datapoint within OR state waters. Each datapoint is labeled with station number and station depth in parentheses.

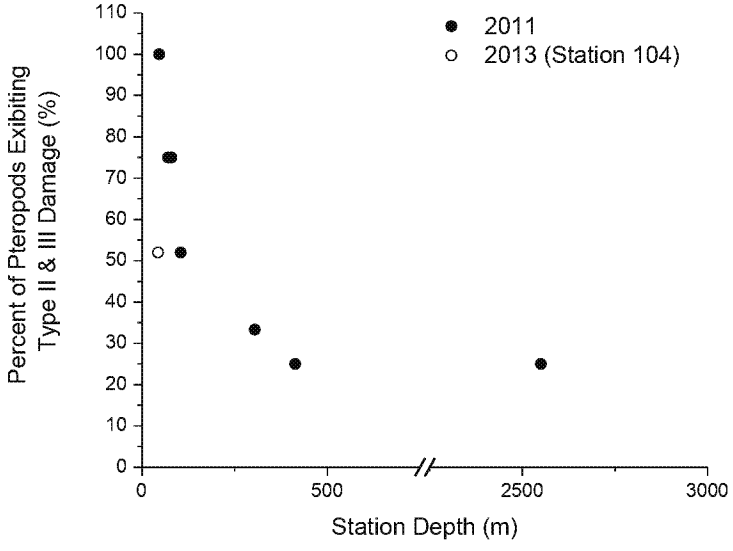


Figure 4. Percent of pteropods exhibiting type II & III damage versus station depth for 2011 stations offshore of Oregon (stations 15,21, 28, 29, 31, and 37) and 2013 within Oregon State Waters (station 104).

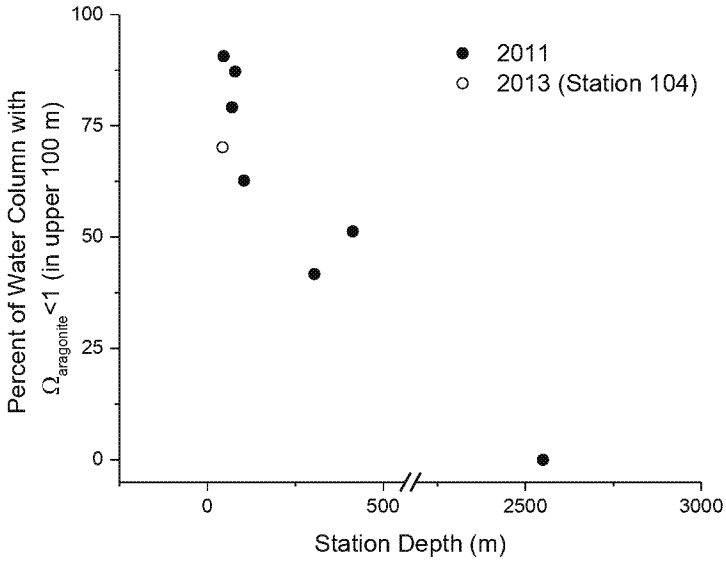


Figure 5. Percent of water column undersaturated (Ω<1) in upper 100 m versus station depth for 2011 stations offshore of Oregon (stations 15,21, 28, 29, 31, and 37) and 2013 within Oregon State Waters (station 104). .

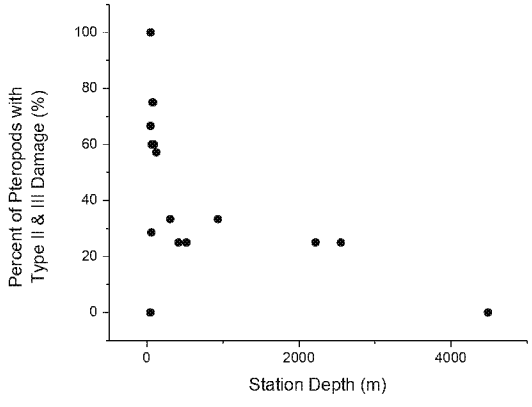
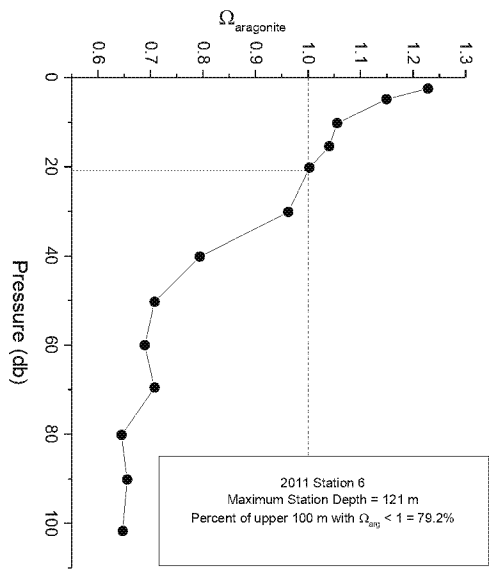


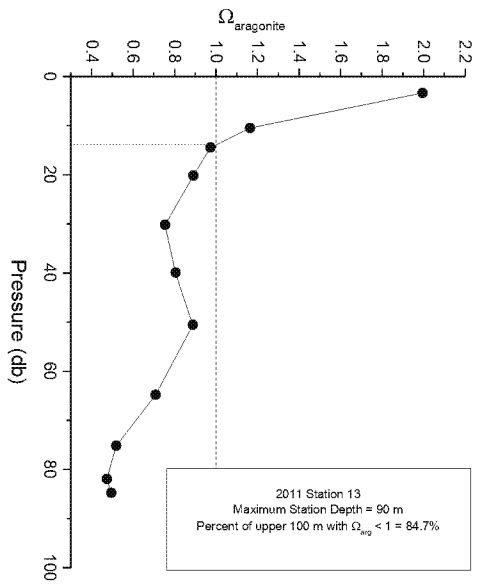
Figure 6. Percent of pteropods with type II & III damage versus station depth (all stations 2011).

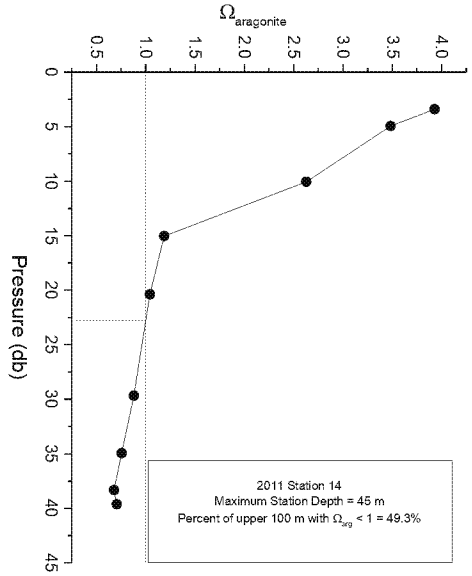
References

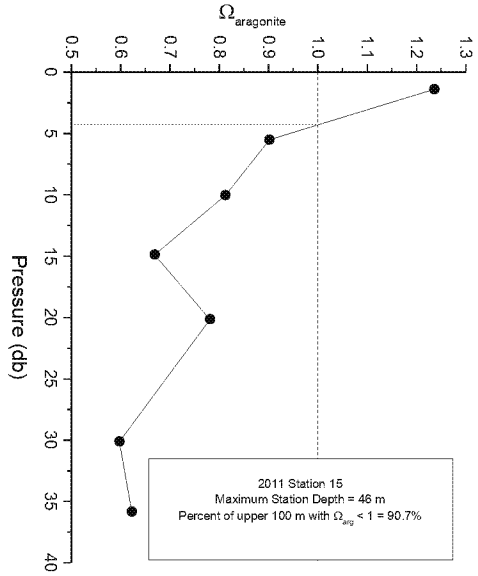
Bednarsek N, Feely RA, Reum JCP, Peterson B, Menkel J, Alin SR, Hales B. 2014. *Limacina helicina* shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California Current Ecosystem. Proc. R. Soc. B 281:20140123. http://dx.doi.org/10.1098/rspb.2014.0123

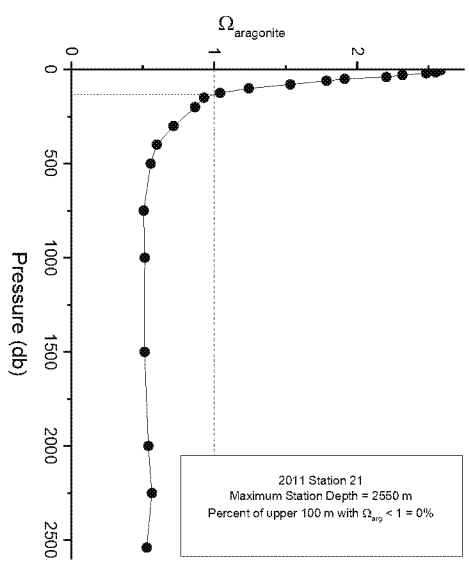
Appendix A: Profiles of 2011 stations and 2013 station within Oregon State Waters.

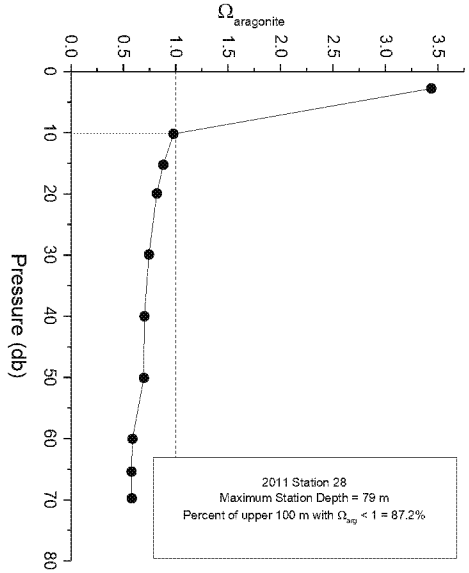


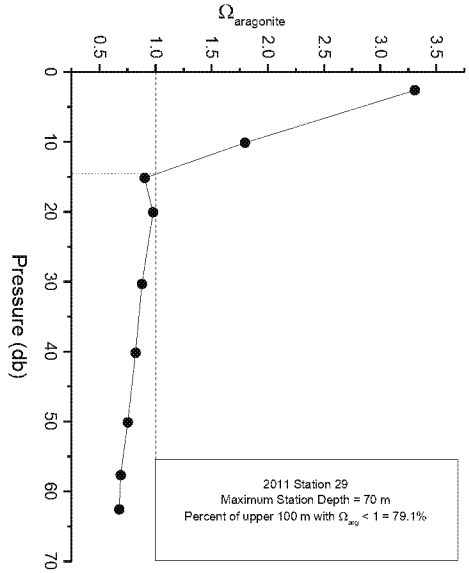


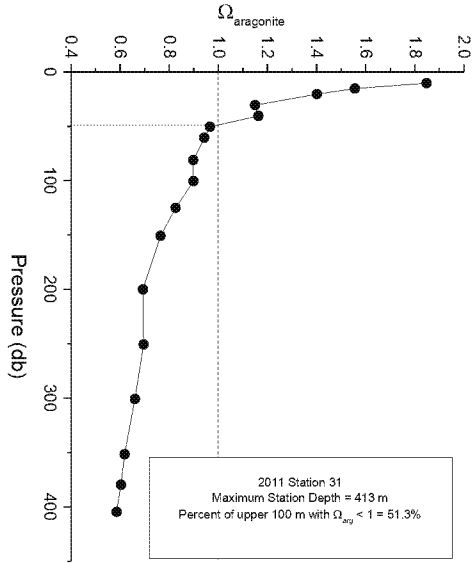












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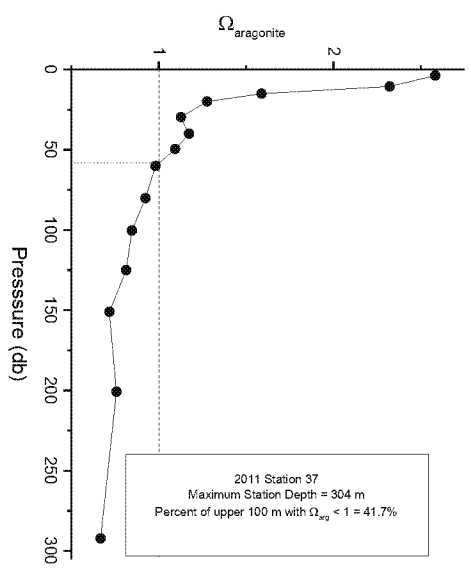
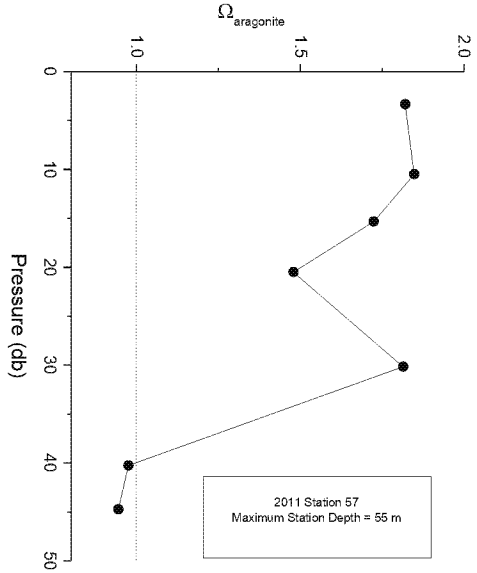
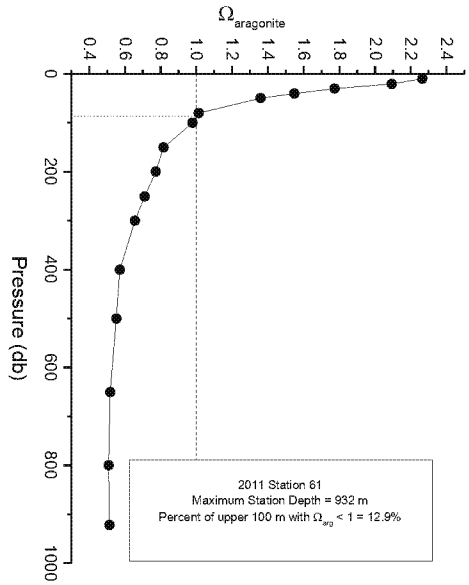
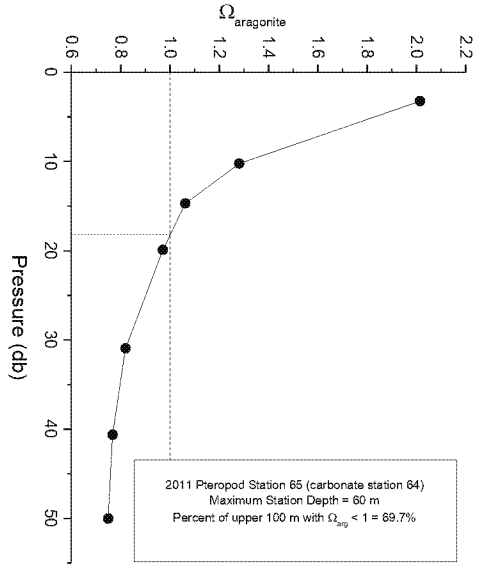
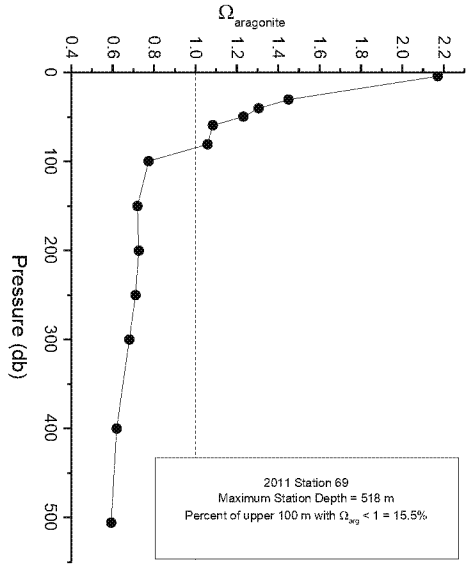
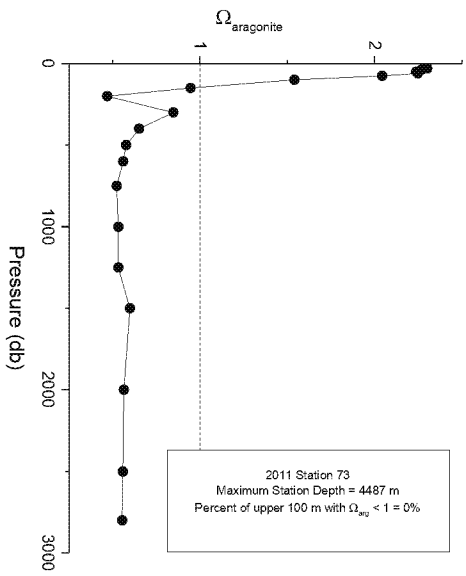

$\Omega_{aragonite}$
Presssure (db)
2011 Station 37
Maximum Station Depth = 304 m
Percent of upper 100 m with Ω_{arg} < 1 = 41.7%

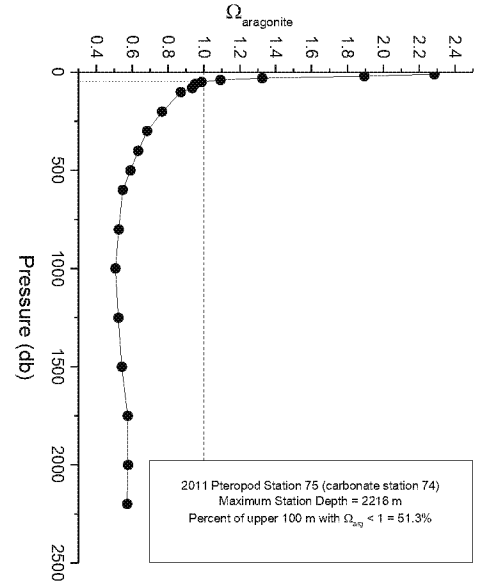

$\Omega_{aragonite}$
Pressure (db)
2011 Station 57
Maximum Station Depth = 55 m

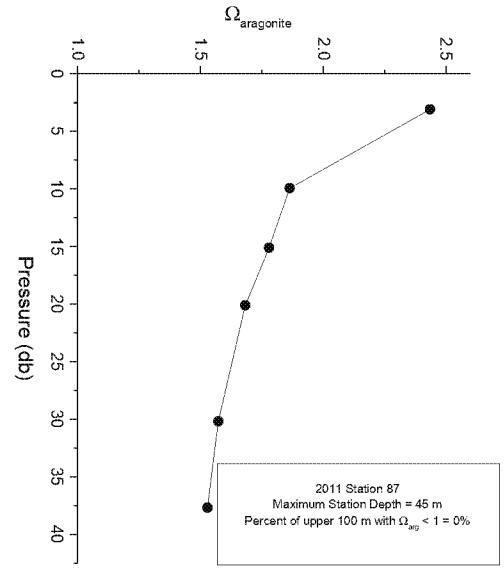

$\Omega_{aragonite}$
Pressure (db)
2011 Station 61
Maximum Station Depth = 932 m
Percent of upper 100 m with Ω_{arg} < 1 = 12.9%

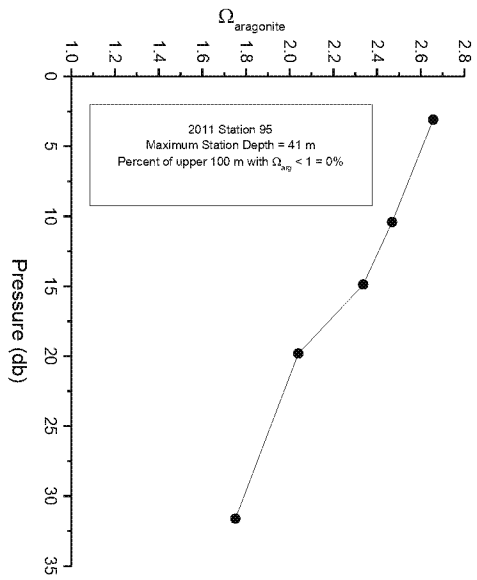

$\Omega_{aragonite}$
Pressure (db)
2011 Pteropod Station 65 (carbonate station 64)
Maximum Station Depth = 60 m
Percent of upper 100 m with Ω_{arg} < 1 = 69.7%

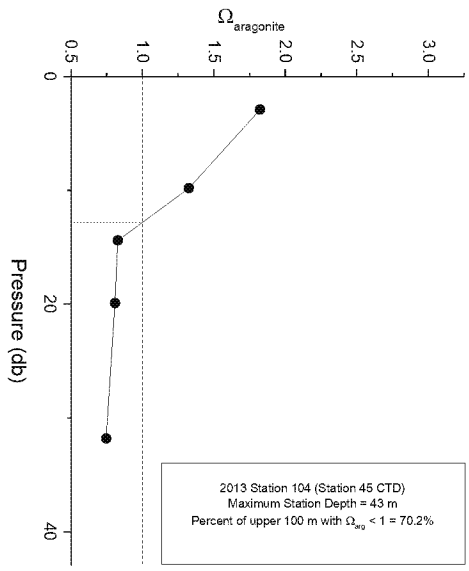

$\Omega_{aragonite}$
Pressure (db)
2011 Station 69
Maximum Station Depth = 518 m
Percent of upper 100 m with Ω_{arg} < 1 = 15.5%


$\Omega_{aragonite}$
Pressure (db)
2011 Station 73
Maximum Station Depth = 4487 m
Percent of upper 100 m with Ω_{arg} < 1 = 0%


$\Omega_{aragonite}$
Pressure (db)
2011 Pteropod Station 75 (carbonate station 74)
Maximum Station Depth = 2218 m
Percent of upper 100 m with Ω_{arg} < 1 = 51.3%


$\Omega_{aragonite}$
Pressure (db)
2011 Station 87
Maximum Station Depth = 45 m
Percent of upper 100 m with Ω_{arg} < 1 = 0%


$\Omega_{aragonite}$
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
0
5
10
15
20
25
30
35
Pressure (db)
2011 Station 95
Maximum Station Depth = 41 m
Percent of upper 100 m with Ω_{arg} < 1 = 0%


$\Omega_{aragonite}$
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
Pressure (db)
2013 Station 104 (Station 45 CTD)
Maximum Station Depth = 43 m
Percent of upper 100 m with Ω_{arg} < 1 = 70.2%

Appendix B: Figure 3 from Bednarsek et al (2014)highlighting datapoints offshore of Oregon. Right panel shows 2011 sampling locations offshore of Oregon.